Two Spectrometers on a Chip

Completed Technology Project (2018 - 2021)

Project Introduction

The promise of miniaturized millimeter-wave (mmw) spectrometers to provide sensitive and highly specific detections of volatile materials in normal and extreme environments has recently been demonstrated in the Spectrometer-on-a-Chip (SpecChip) project. These efforts show that specific organic and inorganic species are readily identified and quantified utilizing a miniaturized Fabry-Perot cavity coupled to a single circuit board containing the mmw production and detection circuitry. These efforts also quantified the sensitivity of the system, the bandwidth, and identified the limiting technologies. Building upon this success, we propose here to improve the extend the bandwidth and range of the supporting CMOS technology to support science goals. We push the boundary of two technological limiting factors for mini-mmw spectrometers (1) to extend the coverage in W-band (covering HDO at 80.6 GHz) and (2) to provide frequency coverage up to G-band (for H2O at 183 GHz). The two chipsets will be shown to operate in a single system, the SpecChip^2. These developments enable the highly desirable science targets of quantifying both water (H2O) and deuterated water (HDO). These measurements in tandem enable H/D ratio measurements in water/ice samples and expand the existing ability to detect and quantify organic and inorganic volatiles. The improvement in frequency range and bandwidth also expands the applicability of CMOS spectrometers to enantiomeric specific measurements. The demonstrated low-mass, low power millimeter wave system with CMOS components covers 89-104 GHz and gas detections of CH3OH, CH3CHO, N2O, OCS, CH3CH2OH, CH3CN, CH3CH2CN, (CH3)2CO, NaCl and KCl have been made. The demonstrations are limited by sample availability and are only a fraction of the gases detectable with such a system. However, there are key species of scientific interest whose target transitions are at higher frequencies, particularly H2O at 183 GHz (in G-band 140-220 GHz) and HDO at 80.6 GHz (in W-band 75-110 GHz). Thus far, 65 nm CMOS tunable devices with sufficient (> 1 mW) power to pump a mixer or a molecular transition, have not been demonstrated above 140 GHz. For infusion of this technique into space missions, we must be able to achieve detections for the highest-value science targets, therefore we propose to develop, fabricate and test the necessary circuitry in 28 nm CMOS, an architecture that is showing improvements for upper frequency limits. Through creation of the specific W-band and G-band circuitry necessary for planetary science instrumentation, we provide a broadly useful new instrument with a premier science capability for water H/D ratio measurement.

Anticipated Benefits

Observations of the solar system and universe have focused on water because of its central importance to life as we know it as well as its ubiquity. The SpecChip2 will feature water measurements, and also provide capability for organic and inorganic surveying. This detection and quantification of matter on early solar system bodies elucidates the initial stages, condition and processes

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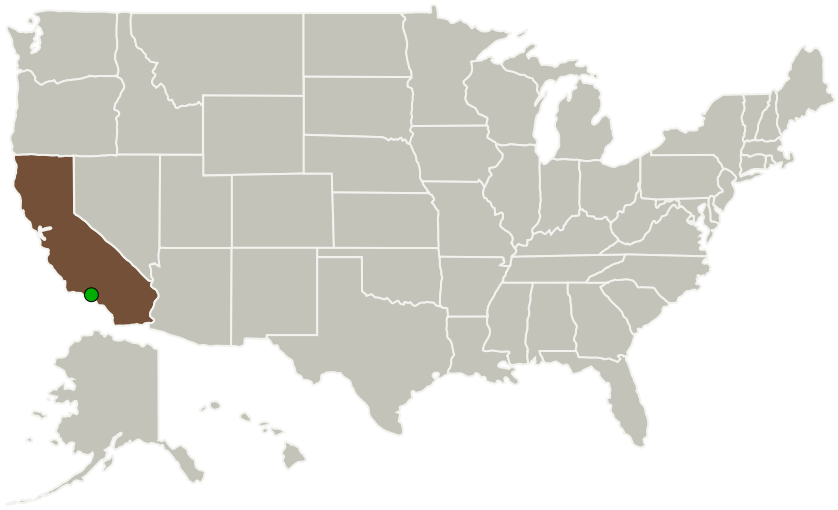
of solar system formation, informs knowledge of the accretion, water supply and evolution of the bodies. Thus the SpecChip2 is a tool to address cross-cutting themes associated with building new worlds. It is a generally useful tool to determine workings of solar systems because it will inform a myriad of chemical processes that shape the operation, interaction and evolution of any solar system body. At specific targets, such as Enceladus, Europa, Mars or Titan, the SpecChip2 also informs planetary habitability through quantitative measurements of water and identification of organic matter that may then be classified as primordial, or freshly synthesized, based on stability, relative abundance, and isotopic ratios. Thus a SpecChip2 is a high value addition to a comet-surface sample return (CSSR) mission, a Saturn, Uranus or Venus Probe, a Mars sample return, or any Discovery mission involving in-situ sampling

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

California Institute of Technology (CalTech)

Responsible Program:

Planetary Instrument Concepts for the Advancement of Solar System Observations

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Haris Riris

Principal Investigator:

Brian J Drouin

Co-Investigators:

Adrian J Tang
Mau-chung Frank Chang
Karen R Piggee
Theodore J Reck

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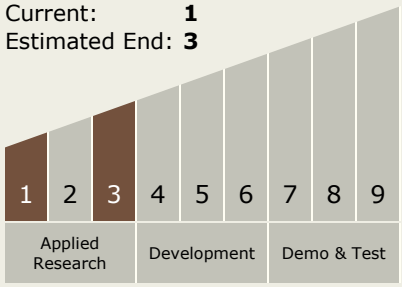
Organizations Performing Work	Role	Type	Location
California Institute of Technology(CalTech)	Lead Organization	Academia	Pasadena, California
Jet Propulsion Laboratory(JPL)	Supporting Organization	NASA Center	Pasadena, California
University of Southern California(USC)	Supporting Organization	Academia	Los Angeles, California

Primary U.S. Work Locations
California

Technology Maturity (TRL)

Start: **1**
Current: **1**
Estimated End: **3**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.1 Remote Sensing Instruments/Sensors
    - TX08.1.4 Microwave, Millimeter-, and Submillimeter-Waves

Target Destination

Others Inside the Solar System